

# EXHIBIT 4

UNITED STATES DISTRICT COURT  
EASTERN DISTRICT OF MICHIGAN  
SOUTHERN DIVISION

MICHIGAN STATE A. PHILIP  
RANDOLPH INSTITUTE,  
COMMON CAUSE, MARY  
LANSDOWN, ERIN COMARTIN  
and DION WILLIAMS,

No. 2:16-cv-11844

HON. GERSHWIN A. DRAIN

Plaintiffs,

v  
RUTH JOHNSON, in her official  
capacity as Michigan Secretary of  
State,

MAG. MONA K. MAJZOUN

Defendant.

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Report of Stephen C. Graves, Ph.D.

1. My name is Stephen C. Graves. I am the Abraham J. Siegel Professor of Management at the Massachusetts Institute of Technology, where I teach graduate and undergraduate subjects and do research in the fields of operations management, supply chain management and manufacturing systems.

2. I have been an active member and participant in the Caltech/MIT Voting Technology Project since its initiation immediately after the 2000 election. The Caltech/MIT Voting Technology Project was established by Caltech President David Baltimore and MIT President Charles Vest in December 2000 to study all aspects of the election process so as to prevent a recurrence of the problems that threatened the 2000 U.S. Presidential Election. My main contributions within this project have been in terms of the operations of polling place and how these might be improved. With my graduate student Rong Yuan, I designed and implemented a software tool to aid in the design and planning of polling places, based on queuing theory. This tool uses queueing theory to calculate the minimal number of service

stations at a process step in a polling place so as to satisfy a service target on maximum waiting times. A process step could be the act of voting, in which case the service stations correspond to voting machines or voting booths. This tool is posted on the Caltech/MIT Voting Technology Project web site, <http://web.mit.edu/vtp/index.html>.

3. I received A.B. and M.B.A. degrees from Dartmouth College in 1973 and 1974, respectively, and an S.M. and Ph.D. degrees from University of Rochester in 1976 and 1977, respectively.

4. I joined the MIT faculty in 1977 as an assistant professor, was promoted to associate professor with tenure in 1985, and then was promoted to full professor in 1987.

5. I served as the Deputy Dean of the MIT Sloan School of Management from September 1990 to August 1993. I served as the Interim Director of the Engineering Systems Division from September 2012 to December 2013. I was elected and served as the Chair of the MIT Faculty from July 2001 to June 2003.

6. I am a Fellow of INFORMS (Institute For Operations Research and the Management Sciences), the leading international association for professionals in operations research and analytics. I am a Fellow of the Manufacturing and Service Operations Management Society (MSOM), and a Fellow of the Production and Operations Management Society (POMS). MSOM and POMS are the two most prominent international organizations for academics in the field of operations management.

7. During my forty years at MIT, I have been responsible for a variety of subjects in operations management, supply chains and systems optimization and analysis. I have taught both elective and required subjects at the graduate level, mainly for students in professional masters programs. In addition, I teach a project-based supply chain class for undergraduates.

8. In 2013, I was asked to make a presentation before the Presidential Commission on Election Administration (PCEA), on the topic of how queuing theory and concepts might help election officials improve the operations of polling places and reduce waiting times. The PCEA was established by Executive Order after the 2012 elections by President Obama. Its mission was to identify best practices in election administration and to make recommendations to improve the voting experience.

9. I have authored around 80 articles in peer-reviewed journals, 20 papers in refereed proceedings, and co-edited two handbooks on the methodology of operations management and supply chain management. (See my c.v., which appears as Exhibit 1.)

10. I have conducted collaborative research projects with numerous companies including AT&T, IBM, Monsanto, Eastman Kodak, Amazon.com, Intel, General Motors, Boeing, Teradyne, Staples, Samsung and Mitsubishi. The nature of this research entails the mathematical modeling and optimization of their systems for production and distribution.

11. I have been retained by the State of Michigan to provide expert testimony in this case. I am compensated for my time at the rate of \$300 per hour. I have not previously testified as an expert witness. See Exhibit 1 for my full curriculum vitae.

### **Introduction to Assessment**

12. I have been asked by the counsel for the Secretary of State for the State of Michigan (Defendant) to provide an assessment of the expert report submitted by Professor Ted Allen on behalf of the Plaintiffs for Case No. 2:16-cv-11844, Michigan State A. Phillip Randolph Institute et al. v. Ruth Johnson.

13. Professor Allen's report offers his "opinions as to the effects of the elimination of straight ticket voting because of 2015 PA 268."<sup>1</sup> Professor Allen concludes that the elimination of straight-ticket voting (STV) will increase the time it takes to vote, and that these increased service times will result in increased waiting time at the polls. Professor Allen argues that this impact will have "a disproportionately negative effect on African Americans deterring tens of thousands from voting."<sup>2</sup>

14. There are two major shortcomings in the analysis that was performed to support these findings.

15. First, the report provides no evidence that the voting times would increase if STV were eliminated. Instead, the report assumes that the voting time will increase by a specified amount; however, the logic justifying this specification is questionable, as set forth in more detail below.

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<sup>1</sup> Allen Expert Report, paragraph #1.

<sup>2</sup> Allen Expert Report, paragraph #1.

16. Second, a simulation is then used to develop predictions on how the waiting time will increase due to the assumed increase in the time to vote if STV were eliminated. The parameters for the simulation are based on data gathered from the 2016 November Election at 31 precincts in Michigan. These parameters were chosen in an attempt to replicate the observed waiting time from the 2016 November Election at these precincts. The report assumes that this waiting time occurs entirely at the voting booths; but this is an invalid assumption as in the actual 2016 election, the observed waiting occurred almost entirely at the registration table<sup>3</sup>. Furthermore, at the three most congested precincts (Saginaw 16, Flint 2, Detroit 1-271), the number of voting booths assumed in the simulation appears to be arbitrarily reduced. The justification<sup>4</sup> given in the Allen report for this adjustment is to assure that the simulation predictions match the actual observed wait time. Again, this adjustment is highly questionable as the observed wait times occurred primarily at the registration table, whereas the simulation is modeling the wait times at the voting booths. As a consequence of these issues, the simulation does not provide a valid representation of the 31 precincts, especially at the three precincts at which the number of voting booths were changed. Hence, the predictions from the simulation for these precincts are deemed as not being reliable.

17. Because of these concerns, I cannot concur with the findings from Professor Allen's report. First, the assertion that the STV elimination will increase the time to vote is at best a conjecture. And even if we were to accept this assertion, the output from the simulation is not convincing and the predicted impact on waiting time at the polls is questionable.

### **Lines at Polling Places**

18. I have performed this assessment based on my knowledge of election administration in general and polling place practices in particular, which has been derived from my involvement in the Caltech/MIT Voting Technology Project since 2000.

19. As part of the Caltech\MIT Voting Technology project, I served as a resource with Professor Charles Stewart, MIT, who wrote *Managing Polling Place*

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<sup>3</sup> This assertion is based on the data sheets that were shared with me and that recorded wait times at the sample of 31 precincts for the 2016 November Election.

<sup>4</sup> Allen Expert Report, paragraph # 19.

*Resources*,<sup>5</sup> which is a report that discusses the applicability of queuing theory to polling place practices, gives practical advice about how election officials might adapt those practices to their management of elections, and gives two case studies.

20. According to the discipline of queuing theory, the core to understanding how long customers — or voters, in the case of elections — will wait to be served in a system is to focus on three attributes.<sup>6</sup> These attributes are:

- Arrival rates: How rapidly do voters arrive to the polling place on a per-unit-time basis (e.g., average arrivals per hour or minute)?
- Service times: How long does it take a voter to perform a relevant task related to voting (e.g., average check-in time, in minutes)?
- Service stations: How many service locations are available to handle voter tasks (e.g., poll books)?

21. From queuing theory we know that, holding everything else constant, voters will wait in longer lines on Election Day if more voters come to the polls, or if it takes them longer to check in, vote, or scan ballots, or if there are fewer poll books, voting booths, and tabulators in a precinct. What is less intuitive is that the queuing systems like those in polling places exhibit non-linear behavior: as queuing systems become more congested, the length of the lines and waiting times can grow much more rapidly.

22. One important complication in the application of queuing models to polling places is that most polling places possess more than one possible queue.<sup>7</sup> In the State of Michigan, which has paper ballots and electronic tabulators, it is possible for lines to form waiting (1) to check in, (2) to vote at a booth, and (3) to scan the ballot at a tabulator.

23. In analyzing the queuing at a polling site, it is very important to account for the interactions between these process steps in voting, namely the process steps of check-in, voting in a booth, and scanning the ballot at the tabulator. Often one of

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<sup>5</sup> <http://web.mit.edu/vtp/Managing%20Polling%20Place%20Resources.pdf>. The executive summary may be found at <http://web.mit.edu/vtp/Managing%20Polling%20Place%20Resources%20executive%20summary.pdf>.

<sup>6</sup> An introduction to queuing theory as applied to polling places may be found at Charles Stewart III, “Managing Polling Place Resources,” Report of the Caltech/MIT Voting Technology Project, <http://web.mit.edu/vtp/Managing%20Polling%20Place%20Resources.pdf>.

<sup>7</sup> Stewart, “Managing Polling Place Resources,” 17.

the process steps is the bottleneck, and the bottleneck will often dictate where and how any queue will form.

24. In the following paragraphs, we will use an example to clarify what we mean by a bottleneck, and how influential it can be in understanding how and where waiting can occur in a multi-step service system.

25. We consider a hypothetical polling site with no process variability; that is, there is no variation in the service time for each process step. The specification for the example is as follows:

Process Step	Number of stations	Task Time (seconds)
Check In	1	60
Vote in a booth	6	300
Scan ballot at tabulator	1	15

26. There is a single check-in station or registration table, and it takes exactly 60 seconds or 1 minute to check the registration of a voter. Hence, the check-in station can process 60 voters per hour.

27. The next process step is to vote in a voting booth. There are 6 identical voting booths, and we assume that it takes exactly 300 seconds or 5 minutes for a voter to complete his or her ballot. Thus, each booth can process 12 voters per hour (i.e., one voter every 5 minutes); and hence, the 6 stations can process 72 voters per hour.

28. There is a single tabulator for scanning the completed ballots. It takes 15 seconds to scan a ballot. Thus, 4 ballots can be scanned per minute, or equivalently 240 ballots can be scanned per hour.

29. For this system, the bottleneck is the check-in step, as it has a capability to process 60 voters per hour. The next step, voting, has a capability to process 72 voters per hour while the last step, scanning, can handle 240 voters per hour. In this system, we would expect that if there were any queuing, it will occur at check in.

30. In order to understand what might happen on a typical Election Day, suppose that the arrival rate during the opening hours on Election Day is exactly 70 voters per hour for three hours from 7 AM to 10 AM. Now consider what happens at the check-in station. It can only process 60 voters per hour. So if 70 voters

arrive uniformly between 7 AM and 8 AM, we expect that check-in will process only 60 of them within the hour and that there will be 10 of these voters in line at 8 AM. If another 70 voters arrive uniformly between 8 AM and 9 AM, again we will only process 60 voters, and the number in line at 9 AM will grow by another 10 voters to be 20 voters. Similarly by 10 AM, we expect that there will be 30 voters in line at check-in.

31. It will take the check-in station 30 minutes to process the 30 voters waiting in line at 10 AM. Hence, the voter that arrives at 10 AM and is the 30<sup>th</sup> voter in line will wait 30 minutes in this line before being checked in. Furthermore, we can determine that the average wait time for the 210 voters that arrived between 7 and 10 AM is 15 minutes at check-in.

32. Now let's consider what happens at the next process steps in the voting system. There will be virtually no waiting elsewhere in the system because the check-in station is the bottleneck in this example. After check-in the voters go to the voting booths to complete their ballots. But check-in can only process 60 voters per hour. Thus, the number of voters that arrive to the voting booths will be at most 60 voters per hour. Assuming that these voters complete check-in at a uniform rate (one per minute), then the arrivals to the voting booths will also be uniform. Since the voting booths can handle, in total, 72 voters per hour, it has sufficient capacity to handle the arrivals of 60 per hour and there should be no delays in accessing a voting booth.

33. Similarly at the last step, scanning, where there is capacity to process 240 voters per hour, there should be no queuing. The output from check-in is at most 60 per hour, which determines the maximum arrival rate for the scanner, and again there is ample capacity to handle this.

34. In summary for this system, the average waiting time for the 210 voters that arrive between 7 and 10 AM is 15 minutes and this wait occurs entirely at the check-in station. The maximum wait is 30 minutes. There is no waiting elsewhere in the system; that is there is no waiting for a voting booth or for the scanner.

35. This behavior is because the check-in station is the bottleneck for the system: it can only process 60 voters per hour, whereas the voting step and scanner have greater capabilities, namely 72 voters per hour and 240 voters per hour, respectively.

36. Now suppose that the time to vote increases from 5 minutes (300 seconds) to 5.5 minutes (330 seconds) for some reason. Each voting booth can now handle

slightly less than 11 voters per hour, and in total, the 6 booths can process about 65 voters per hour. Yet there will still be no waiting in front of the voting booths, even though the voters are arriving to the voting site at a rate of 70 per hour, greater than the capacity at the voting booths. This is because the check-in station is the bottleneck and can only process the voters at 60 per hour, and hence, can only ‘feed’ voters to the voting booth at this rate of 60 per hour. There will still be substantial waiting prior to check-in, as discussed in paragraph #30.

37. I dwell on this example as it is important to appreciate how a bottleneck, especially if it is the first process step, can affect where and how queues will form in a multi-step system. This understanding will be critical in the assessment of the expert report.

### **Voting Times**

38. The analysis presented in Professor Allen’s report is based on the premise that the elimination of STV will increase the time it takes for a voter to complete the ballot. Yet the report provides no evidence in support of this premise. Rather the report makes an assumption that the vote time will increase; this assumption is stated as: “Studying the data in Exhibit A of this report and the sample ballots, I estimate that eliminating the option of straight ticket voting would increase the service time of a voter who had previously used straight ticket voting 25% or more.”<sup>8</sup>

39. The Allen report provides an equation that is used to predict how the vote time will increase; this equation<sup>9</sup> is as follows:

$$\text{Est. Avg. Voting Service Time} = (2016 \text{ Est. Avg.}) \times (1 + \% \text{Straight Ticket Voting} \times \frac{1}{4})$$

40. This calculation from the Allen report is based on the assumption that the average vote time for a voter who used STV is the same as the average time for a voter that voted a mixed ballot<sup>10</sup>. That is, the equation is based on two assumptions: first, it assumes that in 2016 the average time for a STV voter is the same as the average time for a voter who does not vote STV, namely votes a mixed or split ticket.<sup>11</sup> And second, it assumes that if STV were eliminated, the time to vote for the voters that previously used STV would increase by 25%.

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<sup>8</sup> Allen Expert Report, paragraph #18.

<sup>9</sup> Allen Expert Report, paragraph #18.

<sup>10</sup> Allen Expert Report, paragraph #18.

<sup>11</sup> Michigan Ballot Production Standards, page 12, for definition of mixed and split tickets.

41. As an illustration, let's consider the precinct of Meridian 1. For the data collected from 2016 November election, the estimated average time to vote is reported to be 6.16 minutes from Exhibit A in the Allen report. Exhibit A in the Allen report also notes that in Meridian 34.8% of the voters voted a straight-ticket. The Allen report assumes that in 2016 that the average time to vote is 6.16 minutes for the STV voters, namely 34.8% of the voters; and it assumes the average time to vote is also 6.16 minutes for the non-STV voters, namely the remaining 65.2% of the voters.

42. In projecting the impact of an elimination of STV, the Allen report then assumes that for the STV voters, their average time to vote will increase by 25%; that is, the time to vote for 34.8% of the voters will increase by 25% from 6.16 minutes to 7.70 minutes. For the non-STV voters (the remaining 65.2%), their time to vote will remain at 6.16 minutes. The average time to vote is then computed as (and agrees with number given in Exhibit A):

$$34.8\% \times 7.70 \text{ minutes} + 65.2\% \times 6.16 \text{ minutes} = 6.70 \text{ minutes.}$$

43. Although the above formula is in a different form than the equation above in paragraph 39, it is equivalent as shown below:

$$\begin{aligned} & 34.8\% \times 7.70 \text{ minutes} + 65.2\% \times 6.16 \text{ minutes} \\ &= 6.16 \text{ minutes} \times (34.8\% \times 1.25 + 65.2\%) \\ &= 6.16 \text{ minutes} \times (34.8\% (1 + \frac{1}{4}) + 65.2\%) \\ &= 6.16 \text{ minutes} \times (1 + 34.8\% (\frac{1}{4})) \\ &= (2016 \text{ Est. Avg.}) \times (1 + \% \text{Straight Ticket Voting} \times \frac{1}{4}) \\ &= 6.70 \text{ minutes.} \end{aligned}$$

44. This model for projecting the impact on voting time from the elimination of STV can be questioned on two points.

45. First, Allen's report assumes that the current average time to vote is no different between STV and non-STV voters. If there were currently no difference in time to vote, then why would the time to vote increase for the STV voters when STV is eliminated. As the example above shows, why would it take one group of voters 7.70 minutes to vote a mixed or split ticket, whereas another group of voters can do this in 6.16 minutes? This is not logical.

46. Second, Allen's assumption that the time to vote increases by 25% appears to be based on an examination of ballots from a recent election and Allen's observation that "...the partisan section is approximately half of the total ballot."<sup>12</sup> The report's assumption seems to rely on an unstated presumption as to how one votes.

47. For instance, the assumption might be consistent with the presumption that an STV voter spends effectively no time on the partisan part of the ballot and can just immediately check off his or her party of choice, and then spends the rest of their time deliberating and voting on the remainder of the ballot. And then if there were no STV, this voter would need to deliberate on the partisan races before deciding how to vote. In this case, it is conceivable that the elimination of STV would increase the time to vote for that voter.

48. But as noted, this is one story as to how a voter might behave, and one can easily imagine alternatives. For instance, possibly the voter first deliberates on the partisan races and decides whether or not to vote a straight-ticket. As such, the voter will review each of the partisan races to see how he or she wishes to vote, and then decide whether or not to use the STV option. If it so happens that the voter decides to vote a straight-ticket, then the straight-ticket option can be chosen and possibly a few seconds saved, compared with marking each of the partisan races. In this case, eliminating the straight-ticket option is not likely to have any impact on the vote time and actually might even decrease the time to vote, as the voter would not have to deliberate at all as to whether or not to vote a straight-ticket. Rather the voter just deliberates on each race sequentially.

49. As noted, the expert report of Professor Allen does not provide supporting evidence as to the nature of voting behavior that could help to predict the impact of the elimination of STV on the time to vote. And the assumed adjustment of 25% to the time to vote is questionable.

### **Simulation**

50. To predict the impact from an elimination of STV, Professor Allen has used a simulation. To parameterize the simulation, he uses data collected from 31 precincts for the 2016 November Election. He uses this data to get an estimate of the average time to vote, along with the number of voting booths.

51. The Allen report does not provide sufficient information on the simulation as would be necessary to replicate or check the reported results. In particular, to check

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<sup>12</sup> Allen Expert Report, paragraph #18.

the simulation, one would need to know how the voter arrival process is being modeled, and what is being assumed about the distribution of service times. One would also need to know the number of simulation replications that were used for reporting the performance measures, namely the average wait times and the maximum wait times.

52. For the arrival process, due to a lack of information, my best guess is that the simulation assumed that the number of arrivals matched that for the 2016 November Election, namely the number of votes cast on Election Day at each precinct. But the Allen report does not indicate whether the arrival rate varied over the course of the day, and if so, how.

53. Nevertheless, based on the information provided on the Allen report, there are a few serious issues with this application of simulation and with the conclusions being drawn from the results.

54. First, the simulation only models the queuing in front of the voter booths. The simulation is based on an assumption that the voting booths will be the bottleneck at each polling site, and as such, that queuing will occur in front of the voting booths, after check-in (or the registration table).

55. This assumption is not consistent with what happened in the 2016 November Election for the 31 precincts that were modeled in Exhibit A in Allen's report. Overwhelmingly, the queuing at these precincts mainly occurred prior to check-in, as apparently this was the bottleneck; and there was very little if any queueing in front of the voting booths.

56. As evidence that the bottleneck was at the registration table, I examined the data<sup>13</sup> that was collected at these 31 precincts and computed the average waiting time observed in front of the voting booths. The results are shown in the following Table A.

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<sup>13</sup> The data collection protocol consisted of observing a single voter in each half hour of the day. For each observed voter, the observer recorded the time the voter joined the line, the time the voter reached the registration table, the time the voter leaves the registration table, the time the voter enters the voting booth, the time voter leaves the voting booth, and the time the voter leaves the polling place. For each precinct, a maximum of 27 voters could be observed in the voting day, running from 7 AM to 8 PM.

City or Township	Precinct	ave. wait time: total	ave. wait time at voting booths
Allen Park	15	NA	error in coding
Augusta	1	3.33	0.44
Blackman	4	5.86	0.96
Clinton	22	6.52	1.30
Curtis	1	0.54	0.56
Delta	15	4.06	can't read sheet
Detroit	1-271	16.38	2.76
Detroit	4--45	1.86	1.06
Detroit	398	1.99	1.17
Farmington Hills	19	4.94	0.56
Ferndale	2	5.58	0.46
Flint	2	16.63	0.65
Fruitland (Muskegon)	2	10.22	0.38
Gilmore	1	1.30	0.24
Grand Blanc	4	2.46	0.54
Grand Rapids	31	3.57	0.67
Imlay	1	1.08	1.12
La Salle	2	5.08	0.31
Marion	1	5.79	0.10
Marquette	2	3.26	0.26
Meridian	1	8.19	0.11
Oliver	1	0.33	1.21
Ontwa	2	1.12	0.69
Orion	1	3.07	0.17
Peninsula	2	5.70	0.54
Redford Twp.	9	6.48	0.52
Rockford City	2	8.28	0.33
Saginaw	16	52.72	0.03
Shiawasee (Bancroft)	1	6.73	0.12
Troy	5	6.90	0.61
Warren	26	1.33	1.39

Table A: Average wait times (in minutes) observed on Election Day November 2016

57. In Table A, for each precinct I include the total average wait time as is reported in Prof. Allen's report in Exhibit A. In addition, I computed<sup>14</sup> the average wait time between completing registration and entering the voting booth, and include it in the last column of the Table A.

58. With few exceptions<sup>15</sup>, the wait time for a voting booth is a small fraction of the total wait time. As there was no waiting time recorded for scanning the ballot, this implies that the waiting time observed at these precincts occurred primarily prior to check-in. This is consistent with the nation-wide findings from Stewart for the 2012 November election.<sup>16</sup>

59. For instance, consider Saginaw at which the observed total average wait time is nearly 53 minutes. Of this only 0.03 minutes (or 2 seconds) are attributable to wait for the voting booths. Hence, the wait occurs effectively entirely at check-in, and the wait there was on average nearly 53 minutes. We find a similar picture at Flint and at Detroit, precinct 1-271. The total average wait time at Flint is 16.63 minutes, and only 0.65 minutes (39 seconds) is attributable to waiting for a voting booth; the rest is waiting for check-in. For Detroit, precinct 1-271, there is a longer average wait for a voting booth but still it is a small fraction of the total average wait.

60. This analysis strongly suggests that the voting booths were not the bottleneck during the November election of 2016. For the precincts for which the average total wait time was more than two minutes (22 out of 31), the registration table clearly appears to be the bottleneck. For the other 9 precincts, there were either problems with the data and/or very minimal if any waiting; hence, it is less clear for these precincts from the data collected as to whether the bottleneck was at the registration table or not. In any event, from the data collected for these 31

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<sup>14</sup> The wait time to enter the voting booth is the difference between the time that the voter enters the voting booth and the time that the voter leaves the registration table. In the data that I was given, I found on several occasions that this difference was negative: that is, the time that the voter left the registration table was recorded to be after the time the voter was recorded as having entered the voting booth. In virtually all of these instances the difference was a half a minute; for instance, the voter was recorded as leaving the registration table at 9:32:30 and recorded as having entered the voting booth at 9:32. In all of these instances, I treated the wait time for entering the voting booth to be zero, and attribute the discrepancy as being due to the observer's lack of precision in recording the data.

<sup>15</sup> In Table A, there are a few sites at which the average wait for a voting booth is not a small fraction of the total average wait time. At Curtis and Imlay, there was virtually no wait observed at check-in, and the entire wait was prior to the voting booths. But in both sites this wait was minimal, and might be attributable largely to the time for a voter to walk between the registration desk and the voting booth. At Oliver, I could not re-create the estimate given for the total average waiting time. Nevertheless, the data recorded for Oliver is similar to that for Curtis and for Imlay and there was minimal if any waiting at check in. At Warren, I could not re-create the estimate given for the total average waiting time. My calculation for the total average wait time is 2.87 minutes, in which case about half of the wait is attributable to check in and the other half to waiting for a voting booth.

<sup>16</sup> Charles Stewart III, "Managing Polling Place Resources," Report of the Caltech/MIT Voting Technology Project, page 9, Figure 4.

precincts, there was no significant waiting in front of the voting booths at any of the 31 precincts.

61. To properly model the queueing behavior at these sites that experienced waiting of any significance, one should account for the bottleneck; that is, one should include the registration step as part of any predictive model. Just simulating the voting booths, as done in the report from Prof. Allen, is questionable as it ignores the role that the check-in step plays in modulating how voters arrive to the voting booths.

62. An even more serious concern is the adjustments to the number of voting booths, as described in paragraph #19 in the Allen report. For the simulation, the number of voting booths was reduced from 15 to 13 for Detroit 1-271, from 28 to 5 for Flint, and from 25 to 11 for Saginaw. The explanation given was that "...in some cases multiple precincts met together and the observer recorded all resources not merely the ones for the precinct. In general, voters are only permitted to use the resources for their own precincts..."<sup>17</sup> The report goes on to say that "...the resource counts were selected to calibrate the simulation with the measured average waiting times."<sup>18</sup>

63. The explanation asserts that there were multiple precincts voting at these locations, and the number of voting booths noted by the observer corresponded to the total number of voting booths for the location. But according to the explanation, only a portion of these voting booths was available to voters from a particular precinct. The explanation suggests that the number dedicated to the precinct was not observable. I have not been able to confirm or disaffirm this explanation.

64. Nevertheless, the number of voting booths for the three most congested precincts (Saginaw, Flint, Detroit 1-271) was determined in the Allen report so that the average wait time at the voting booths, as predicted from the simulation, matched the observed total average wait time on Election Day November 2016.

65. But this is an "apples and oranges" comparison. The observed total average wait time entails the wait at both the registration table and at the voting booths, with virtually all of the wait occurring at registration. The simulation only predicts the wait time at the voting booths. Setting the number of voting booths so as to fit

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<sup>17</sup> Allen Expert Report, paragraph #19.

<sup>18</sup> Allen Expert Report, paragraph #19.

the simulation output to the observed wait time is not meaningful, as it is comparing “apples to oranges.”

66. As an example, consider the Saginaw precinct. The observed average wait time is on the order of 53 minutes, as reported in Exhibit A of the Allen report. As noted above in Table A, only 2 seconds of this time occurred at the voting booths, and the rest was wait at the registration tables. Nevertheless, for the simulation in the expert report of Prof. Allen, the number of voting booths in Saginaw was reduced from the 25 to 11 so that the simulation would give an average wait time at the voting booths (44 minutes) that was roughly the same as the observed total average wait time of 53 minutes. But this is not meaningful, as there is no evidence to suggest that the Saginaw precinct operated with 11 voting booths in the 2016 November Election. Rather, from the data gathered, it was clear that the registration table was the bottleneck, and that there were always ample voting booths available as effectively no voter had to wait to get a booth.

67. Based on this assessment I conclude that there are two shortcomings related to the simulation application in the Allen report. First is the presumption that the voting booths are the bottleneck, and hence that only the voting booths need to be modeled in the simulation. The data collected from the 2016 November Election clearly refute this presumption. Second is the adjustments that were made to the number of voting booths at the three most congested precincts. These adjustments were made to produce a result, namely to create a particular waiting time at the voting booths, which is counter to the actual observations. As noted above for Saginaw, the adjustments were made so that the simulation produced an average wait time at the voting booths of 44 minutes, even though the observed average wait time was 2 seconds. As such, these adjustments cannot be defended.

### **Predictions from Application of the Simulation**

68. In the Allen report, the simulation is used to predict the impact on wait times from an elimination of STV. This is done by running the simulation with the adjusted service times and with the adjustments to the number of voting booths at several precincts. The results are reported in Exhibit F of the Allen report.<sup>19</sup> The key findings are the predictions that the average wait time would increase at Detroit 1-271 by 58 minutes, at Flint by 65 minutes and at Saginaw by 44 minutes. These were the three precincts in the sample that were the most congested in the

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<sup>19</sup> Allen Expert Report, paragraph 25.

2016 November Election. The simulation also predicts smaller increases at the other precincts.

69. These findings with respect to the impact on waiting times from the elimination of STV are questionable based on the points raised in this assessment.

70. First, the presumption that the elimination of STV will increase the time to vote, and by how much are questionable. The expert report provides no evidence in support of its assumptions for how the time to vote might be affected by the elimination of STV.

71. Second, even if we were to accept this presumption, then the impact on the voter's wait time is questionable due to the shortcomings of the simulation application. The simulation only models the queueing at the voting booths, under the assumption that this is the system bottleneck. This assumption is counter to the evidence from the 2016 November Election in which the bottleneck at all of the polling sites in the sample with actual waiting was at the registration table. Conceivably the bottleneck could shift to the voting booths if the time to vote increases; but the report provides no arguments in support of this.

72. The second shortcoming of the simulation application is the adjustment of the number of voting booths at the three most congested precincts. This adjustment to reduce the number of booths at these sites seems quite arbitrary and as such invalidates any results from the simulation for these precincts.

73. Hence, the simulation analysis as reported in the expert report does not support the conclusions given in the report, and is at best inconclusive with regard to any impact from the elimination of STV.

74. I provide this assessment of the Expert Report prepared by Professor Allen based on the information that has been made available to me. I reserve the right to amend or correct my assessment in light of additional new information.

I declare under penalty of perjury that the foregoing is true and correct. Executed this 3<sup>rd</sup> day of August 2017.

A handwritten signature in cursive script that reads "Stephen C. Graves".

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Stephen C. Graves

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December 2016

## CURRICULUM VITAE

Name: Stephen C. Graves	Department: Sloan School of Management
Date of Birth: November 1951	Place of Birth: Pittsfield, MA
Citizenship: U.S.	Marital Status: Married

### Contents

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### Education

School	Degree	Date
Dartmouth College	A.B.	1973
Dartmouth College	M.B.A	1974
University of Rochester	M.S.	1976
University of Rochester	Ph.D.	1977

Title of Doctoral Thesis: "The Multiproduct Production Cycling Problem for Stochastic Demand and Finite Production Capacity"

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### Principal Fields of Interest

Operations Management  
Applied Operations Research

### Name and Rank of Other SSM Faculty

Gabriel R. Bitran	Professor
Charles. H. Fine	Professor
Steven D. Eppinger	Professor
Georgia Perakis	Professor
Retsef Levi	Professor
Donald B. Rosenfield	Senior Lecturer
Vivek Farias	Associate Professor
Jonas Jonasson	Assistant Professor
Nikolaos (Nikos) Trichakis	Assistant Professor
Yanchong Karen Zheng	Assistant Professor
Tauhid Zaman	Assistant Professor
Zeynep Ton	Adjunct Professor

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### Non-M.I.T. Experience

Employer	Position	Date
Educational Testing Service	Management Science Analyst	Summer 1972
Simonds Saw and Steel	Management Science Analyst	Summer 1973
University of Rochester	Research Assistant	Summer 1974
University of Rochester	Instructor	Summers 75-77
University of Rochester	Visiting Research Associate	Summers 79-80
Eastman Kodak	Management Science Analyst	Summers 80-81
Shanghai Institute of Mechanical Engineering	Visiting Professor	July 82-Jan 83
Optiant	Member of Advisory Board	2000 - 2009
Servigistics	Chief Scientist	2001 - 2004
JDA	Chief Science Advisor	2005 - 2011

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## History of M.I.T. Appointments

Rank	Beginning	Ending
Assistant Professor, Sloan School of Management	7/77	6/81
Associate Professor, Sloan School of Management	7/81	6/87
Professor, Sloan School of Management	7/87	"
Leaders for Manufacturing Professor	7/88	6/93
Deputy Dean	9/90	8/93
Abraham J. Siegel Professor of Management	10/95	"
Professor, Engineering Systems Division (joint)	7/99	6/15
Professor, Mechanical Engineering Department (joint)	7/05	"
Interim Director, Engineering Systems Division	9/12	12/13

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## Industrial Consulting Record

### Firm and Dates

Bausch and Lomb, 1976; Shycon Associates, 1980 - 1986; GTE Research Laboratories, 1981 - 1982, 1984, 1986; Illinois Central Gulf Railroad, 1982; C.S. Draper Laboratory, 1982 - 1984; ROLM Corporation, 1984, 1993; Palladian Software, 1986; GM Research Laboratories, 1986 - 1997, 2003 - 2004; W.R. Grace, 1987, 1991; Millipore, 1988; WearGuard, 1988; Alcoa, 1993 - 1994; Amazon.com, 2001; Invistics, 2002 - 2005; Servigistics, 2001 - 2003; JDA, 2003 - 2011; Honeywell, 2003; FormFactor 2006; McMaster-Carr 2007. Sears Holdings, 2015.

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## Institute Activities

- Staff Member of Operations Research Center, 1977 - 2017
- Undergraduate Advisor, 1978 - 2017
- Freshman Advisor, 1991- 1998, 2002 - 2005, 2008-2017
- Member of Sloan Program Committees: 1978 - 2013(SB); 1978-1980 (SM); 1985-1987, 1994 -1998, 2005 - 2008 (PhD).
- Chair of Sloan Undergraduate Education Committee, 2010-2013
- Member of Committee on Academic Performance, 1984-1986
- Member of Committee of Discipline, 1995 - 1997
- Chair of Committee on Discipline, 1997 - 2001
- Member of Sloan Dean Search Committee, 1987
- Member of Freshman Housing Committee, 1989
- Acting CoDirector, Leaders for Manufacturing Program, 1989-1990

- Member - INFORMS
- Member of Student Affairs Committee for ORSA, 1980-1983
- Edelman Award Committee, " 1988 - 2007; 2011-2012 (Chair)
- INFORMS (formerly TMS/ORSA) Publication Committee, 1990-1998, 2006 - 2008
- Vice President, Publications - INFORMS, 1994 - 1995

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## Awards

- Fellow of the Manufacturing and Service Operations Management Society
- Fellow of the Production and Operations Management Society
- INFORMS Fellow
- 1999 Billard Award for service at MIT
- 2012 MSOM Distinguished Service Award
- Zaragoza Logistics Center: Medal of Distinction (2013)

## Subjects Taught

- 15.062 Decision Models for Management
- 15.761 Operations Management
- 15.763 Practice of Operations Management
- 15.764 Theory of Operations Management
- 15.053 Introduction to Management Science
- 15.770J Transportation and Logistics Analysis
- 15.066J System Optimization and Analysis for Manufacturing
- 15.762 Operations Management: Models and Applications
- 15.762J Supply Chain Planning
- 15.763J Manufacturing System and Supply Chain Design
- 15.A03" Operations Research Can Be Fun (Freshman seminar)
- EC.733J D Lab Supply Chains (15.772J)

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## Publications

### Papers

1. "Optimal Storage Assignment in Automatic Warehousing Systems," (with W.H. Hausman and L.B. Schwarz), *Management Science*, February 1976, Vol. 22, 629-638.
2. "Single Cycle Continuous Review Policies for Arborescent Production/Inventory Systems," (with L.B. Schwarz), *Management Science*, January 1977, Vol. 23, 529-540.
3. "Storage-Retrieval Interleaving in Automatic Warehousing Systems." (with W.H. Hausman and L.B. Schwarz), *Management Science*, May 1977, Vol. 23, 935-945.
4. "A Note on 'Critical Ratio Scheduling: An Experimental Analysis'," *Management Science*, August 1977, Vol. 23, 1358-1359.

- Chair of Parking and Transportation Committee, 1989-1995
- Member of Parking and Transportation Committee 2016-2017
- CoDirector, Leaders for Manufacturing Program, 1994 - 2001
- CoDirector, System Design and Management Program, 1999 - 2001
- Chair of Task Force on ROTC, 1995 - 1996
- Chair of Sloan Dean Search Committee, 1998
- Chair of MIT Faculty, 2001 - 2003
- Chair of Faculty Policy Committee, 2001 - 2003
- Member of Task Force on Campus Security, 2001
- Member, ad hoc committee on Access to and Disclosure of Scientific Information, 2002
- Chair, review committee on Faculty Newsletter, 2002
- Faculty Newsletter, Editorial Board, 2003 – 2009
- Member of Faculty Advisory Committee for MIT Presidential Search, 2004 - 2005
- Member of Committee on Undergraduate Admissions and Financial Aid, 2004 - 2006
- Chair of Committee on Undergraduate Admissions and Financial Aid, 2007 - 2008
- Member of ad hoc committee on MIT Disciplinary System, 2005
- Member of ad hoc committee on MLK Visiting Professor Program, 2006
- Member of Stellar faculty advisory committee, 2004 - 2010
- Chair of Search Committee for Dean of Graduate Student Office, 2007
- Chair of Dean for Graduate Education Search Advisory Committee, 2010
- Chair of Committee on Graduate Policy, 2008 – 2011
- Member of Commencement Committee, 2007 – 2011
- Member of Search Committee for Director of Student Financial Services, 2008- 2009
- Chair of Search Committee for Director of Financial Aid, 2009-2010
- Member of MIT150 Steering Committee, 2008 – 2011
- Chair of ad hoc committee: Strategic Review of MIT Sloan's Undergraduate Programs, 2009
- Member of Education Working Group of the MIT Planning Task Force, 2009
- Member of NGS3 faculty advisory group, 2009- 2011
- Member of Independent Activities Period (IAP) Subcommittee of the FPC, 2012
- Member of Committee on the Undergraduate Program, 2011-2013
- Chair of Committee on the Undergraduate Program, 2013-2014
- Co-chair of Task Force for Graduate Student Professional Development, 2012-2013
- Member of ROTC Oversight Committee, 2012-2014
- Member of Employee Assistance Program (EAP) Advisory Committee, 2015-2017
- Member of Ad Hoc Group on the Future of Libraries, 2015-2016
- Member of Committee on Campus Planning, 2016-2017
- Member of Committee on Community Giving, 2016-2017

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## Professional Activities

- Associate Editor - *Operations Research*, 1981-1986; *Management Science*, 1983-1986, 2001-2003; *Manufacturing & Service Operations Management*, 1997 - 2008, 2017
- Department Editor - *Management Science*, 1987-1991
- Area Editor – *Operations Research*, 2006 – 2008
- Editor - *Manufacturing & Service Operations Management*, 2009 - 2014
- Functional Area Editor - *Interfaces*, 1985-1986
- Editor, Special Issue, *Interfaces*, 1989 - 2007

5. "On 'Production Runs for Multiple Products: The Two-Product Heuristic'," (with R.W. Haessler), *Management Science*, July 1978, Vol. 24, 1194-1196.
- 6.. "Scheduling Policies for Automatic Warehousing Systems: Simulation Results," (with W.H. Hausman and L.B. Schwarz), *AIIE Transactions*, September 1978, Vol. 10, 260-270.
- 7." "A Note on the Deterministic Demand Multi-Product Single-Machine Lot Scheduling Problem," *Management Science*, March 1979, Vol. 25, 276-280.
8. "A Methodology for Studying the Dynamics of Extended Logistics Systems," (with J. Keilson), *Naval Research Logistics Quarterly*, July 1979, Vol. 26, 169-197.
9. "An n-Constraint Formulation of the (Time Dependent) Traveling Salesman Problem," (with K.R. Fox and B. Gavish), *Operations Research*, July-August 1980, Vol. 28, 1018-1021.
10. "The Multi-Product Production Cycling Problem," *AIIE Transactions*, September 1980, Vol. 12, 233-240.
- 11." "A One-Product Production/Inventory Problem with Continuous Review Policy," (with B. Gavish), *Operations Research*, September-October 1980, Vol. 28, 1228-1236.
12. "Production/Inventory Systems with a Stochastic Production Rate Under a Continuous Review Policy," (with B. Gavish), *Computers and Operations Research*, 1981, Vol. 8, 169-183.
13. "Multistage Lot-Sizing: An Iterative Procedure," in TIMS Studies in Management Science, *Multi-Level Production/Inventory Systems: Theory and Practice*, edited by L.B. Schwarz, 1981, Vol. 16, 95-109.
14. "The Compensation Method Applied to a One-Product Production Inventory Model," (with J. Keilson), *Mathematics of Operations Research*, May 1981, Vol. 6, 246-262.
- 15.. "A Review of Production Scheduling," *Operations Research*, July-August 1981, Vol. 29, 646-675.
16. "Problem Formulations and Numerical Analysis in Integer Programming and Combinatorial Optimization," (with J.F. Shapiro), in *Mathematical Programming with Data Perturbations I*, edited by A.V. Fiacco, 1982, 131-148.
17. "Using Lagrangean Techniques to Solve Hierarchical Production Planning Problems," *Management Science*, March 1982, Vol. 28, 260-275.
18. "The Application of Queueing Theory to Continuous Perishable Inventory Systems," *Management Science*, April 1982, Vol. 28, 400-406.
19. "A Multiple-Item Inventory Model with a Job Completion Criterion," *Management Science*, November 1982, Vol. 28, 1134-1137.
20. "System Balance for Extended Logistic Systems," (with J. Keilson), *Operations Research*, March-April 1983, Vol. 31, 234-252.

21. "An Integer Programming Procedure for Assembly System Design Problem," (with B. Lamar), *Operations Research*, May-June 1983, Vol. 31, 522-545.
22. "Scheduling of Re-entrant Flow Shops," (with H.C. Meal, D. Stefek, and A.H. Zeghmi), *Journal of Operations Management*, August 1983, Vol. 3, 197-207.
23. "A Simple Stochastic Model for Facility Planning in a Mental Health Care System," (with H.S. Leff, J. Natkins, and M. Senger), *Interfaces*, October 1983, Vol. 13, 101-110.
24. "Deep-Draft Dredging of U.S. Coal Ports: A Cost-Benefit Analysis," (with M. Horwitch and E.H. Bowman), *Policy Sciences*, Vol. 17, 1984.
25. "A Study of Production Smoothing in a Job Shop Environment," (with A.B. Cruickshanks and R.D. Drescher), *Management Science*, March 1984, Vol. 30, 368-380.
26. "A Minimum Concave-Cost Dynamic Network Flow Problem with an Application to Lot-Sizing," (with J.B. Orlin), *Networks*, Vol. 15, 1985.
27. "Description and Field Test of a Mental Health System Resource Allocation Model," (with H.S. Leff, J. Natkins, and J. Bryan), *Administration in Mental Health*, Fall 1985, Vol. 13, 43-68.
28. "Continuous-Review Policies for a Multi-Echelon Inventory Problem with Stochastic Demand," (with M. DeBodt), *Management Science*, October 1985, Vol. 31, 1286-1299.
29. "A Multi-Echelon Inventory Model for a Repairable Item with One-for-One Replenishment," *Management Science*, October 1985, Vol. 31, 1247-1256.
30. "An LP Planning Model for a Mental Health Community Support System," (with H.S. Leff and M. Dada), *Management Science*, February 1986, Vol. 32, 139-155.
31. "Overlapping Operations in Material Requirements Planning," (with M.M. Kostreva) *Journal of Operations Management*, Vol. 6, No. 3, May 1986, 283-294.
32. "Two-Stage Production Planning in a Dynamic Environment," (with H.C. Meal, S. Dasu, Y. Qiu), in *Lecture Notes in Economics and Mathematical Systems, Multi-Stage Production Planning and Inventory Control*, edited by S. Axsater, Ch. Schneeweiss, and E. Silver, Springer-Verlag, Berlin, 1986, Vol. 266, 9-43. (Sloan WP preprint available to download)
33. "A Tactical Planning Model for a Job Shop," *Operations Research*, July-August 1986, Vol. 34, 522-533.
34. "Equipment Selection and Task Assignment for Multiproduct Assembly System Design," (with C.A. Holmes Redfield) *International Journal of Flexible Manufacturing Systems*, 1988, Vol. 1, No. 1, pp. 31-50.
35. "Safety Stocks in Manufacturing Systems," *Journal of Manufacturing and Operations Management*, 1988, Vol. 1, No. 1, pp. 67-101. (Sloan WP preprint available to download)
36. "Determining the Spares and Staffing Level for a Repair Depot," *Journal of Manufacturing and Operations Management*, 1988, Vol. 1, No. 2, pp. 227-241.

37. "A Composite Algorithm for the Concave-Cost Network Flow Problem," (with A. Balakrishnan) *Networks*, Vol. 19, 1989, pp. 175-202.
38. "A Tactical Planning Model for Manufacturing Subcomponents of Mainframe Computers," (with C. Fine), *Journal of Manufacturing and Operations Management*, 1989, Vol. 2, No. 1, pp. 4-34.
39. "A Model for the Configuration of Incoming WATS Lines," (with R. H. Blake and P. C. Santos), *Queueing Systems*, 1990, Vol. 7, No. 1, pp. 3-21.
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42. "A Multi-Echelon Inventory Model with Fixed Replenishment Intervals," *Management Science*, Vol. 42, No. 1, (January 1996) pp. 1-18.
43. "Cyclic Scheduling in a Stochastic Environment," (with H. Zhang), *Operations Research*, November-December 1997, Vol. 45, 894-903.
44. "A Dynamic Model for Requirements Planning with Application to Supply Chain Optimization," (with D. B. Kletter and W. B. Hetzel)" *Operations Research*, May-June 1998, Vol. 46, Supp. No. 3 pp. S35-49.
45. "OMAC: A System for Operations Modeling and Analysis," (with K. N. McKay and D. B. Kletter)," *Annals of OR*, Vol. 72, 1997, pp. 241-264.
46. "Reducing Flow Time in Aircraft Manufacturing," (with Jackson Chao), " *Production and Operations Management*, Spring 1998, Vol. 7, No. 1, pp.38-52.
47. "A Single-Item Inventory Model for a Non-Stationary Demand Process," *Manufacturing & Service Operations Management*, 1999, Vol. 1, No. 1, pp. 50-61.
48. "Optimizing Strategic Safety Stock Placement in Supply Chains," (with S. P. Willems), *Manufacturing & Service Operations Management*, Winter 2000, Vol. 2, No. 1, pp. 68-83.
49. "Manufacturing Planning and Control," in Handbook of Applied Optimization, edited by P. Pardalos and M. Resende, Oxford University Press, New York, 2002, pp. 728 - 746.
50. "Technology Portfolio Management: Optimizing Interdependent Projects over Multiple Time Periods," (with M. W. Dickinson and A. C. Thornton), *IEEE Transactions on Engineering Management*, November 2001, Vol. 48, No. 4, pp.518 - 527.
51. "Creating an Inventory Hedge for Markov-Modulated Poisson Demand: Application and Model," (with H. S. Abhyankar), *Manufacturing & Service Operations Management*, Fall 2001, Vol. 3, No. 4, pp. 306 - 320.
52. "Process Flexibility in Supply Chains," (with B. T. Tomlin ), *Management Science*, July 2003, Vol. 49, No. 7, pp. 907 - 919.

53. Handbook in Operations Research and Management Science, Volume 11: "Supply Chain Management: Design, Coordination and Operation", edited by A. G. DeKok and S. C. Graves, Elsevier, Amsterdam, 2003.
54. "Supply Chain Design: Safety Stock Placement and Supply Chain Configuration," (with S. Willems), Chapter 3 in Handbook in Operations Research and Management Science, Volume 11: "Supply Chain Management: Design, Coordination and Operation", edited by A. G. DeKok and S. C. Graves, Elsevier, Amsterdam, 2003, pp. 95 - 132.
55. "Optimizing the Supply-Chain Configuration for New Products," (with S. Willems), *Management Science*, August 2005, Vol. 51, No. 8, pp.1165- 1180.
56. "Logistics Network Design with Supplier Consolidation Hubs and Multiple Shipment Options," (with M.L.F. Cheong, R. Bhatnagar), *Journal of Industrial and Management Optimization*, Volume 3, Number 1, February 2007, pp. 51–69.
57. "A Single-Product Inventory Model for Multiple Demand Classes," (with H. Arslan, T. Roemer) *Management Science*, September 2007, Vol. 53, No. 9, pp. 1486 – 1500. On-line companion.
58. "Flexibility Principles," Chapter 3 in Building Intuition: Insights from Basic Operations Management Models and Principles, edited by D. Chhajed and T. J. Lowe, Springer Science+Business Media, LLC, New York, 2008, pp. 33 – 49.
59. "Little's Law," (with J. D. C. Little), Chapter 5 in Building Intuition: Insights from Basic Operations Management Models and Principles, edited by D. Chhajed and T. J. Lowe, Springer Science+Business Media, LLC, New York, 2008, pp. 81 – 100.
60. "Strategic Inventory Placement in Supply Chains: Nonstationary Demand," (with S. Willems) " *Manufacturing & Service Operations Management*, Spring 2008, Vol. 10, No. 2, pp. 278 - 287. On-line companion
61. "The Benefits of Re-Evaluating Real-Time Order Fulfillment Decisions," (with P. Xu and R. Allgor), *Manufacturing & Service Operations Management*, Spring 2009, Vol. 11, No. 2, pp 340-355.
62. "Strategic Safety Stocks in Supply Chains with Evolving Forecasts," (with Tor Schoenmeyr), *Manufacturing & Service Operations Management*, Fall 2009, Vol. 11, No. 4, pp 657-673.
63. "Optimal Planning Quantities for Product Transition," (with Hongmin Li and Donald Rosenfield), *Production and Operations Management*, March-April 2010, Vol. 19, No. 2, pp 142-155.
64. "Uncertainty and Production Planning " in Production and Inventories in the Extended Enterprise , edited by Karl G. Kempf, Pinar Keskinocak, and Reha Uzsoy, International Series in Operations Research & Management Science Volume 151, Springer US, 2011, pp 83 – 101.
65. "Setting Planned Lead Times for a Make-To-Order Production System under Master Schedule Smoothing," (with C. C. Teo and R. Bhatnagar), *IIE Transaction*, 2011, Vol. 43, No. 6, pp. 399-414.
66. "How to Catch a Tiger: Understanding Putting Performance on the PGA Tour," (with Douglas Fearing and Jason Acimovic), *Journal of Quantitative Analysis in Sports*.2011 Vol. 7: Iss. 1 Article 5. DOI: 10.2202/1559-0410.1268. Available at: <http://www.bepress.com/jqas/vol7/iss1/5>

67. "Pricing Decisions during Inter-generational Product Transitions," (with Hongmin Li) *Production and Operations Management*, January-February 2012, Vol. 21, No. 1, pp 14-28.
68. "Remanufacturing and Energy Savings," (with T. Gutowski, S. Sahni, and A Boustani) *Environmental Science & Technology*, 2011, Vol. 45, pp. 4540-4547.
69. "An Application of Master Schedule Smoothing and Planned Lead Time Control," (with C.C. Teo, and R. Bhatnagar), *Production and Operations Management* March-April 2012, Vol.21, No.2, pp211-223.
70. "Ship-Pack Optimization in a Two-Echelon Distribution System," (with Naijun Wen and Justin Ren), *European Journal of Operational Research*, August 2012, Vol. 220, Issue 3, pp. 777- 785.
71. "Optimal Capacity Conversion for Product Transitions under High Service Requirements," (with Hongmin Li and Woonghee Tim Huh), *Manufacturing & Service Operations Management*, Winter 2014, Vol. 16, No. 1, pp. 46-60.
72. "A Forecast-driven Tactical Planning Model for a Serial Manufacturing Systems," (with Pallav Chhaochhria) *International Journal of Production Research*., December 2013, 51:23-24, pp.6860-6879
73. "Water Desalination Supply Chain Modeling and Optimization: The Case of Saudi Arabia," (with Malak T. Al-Nory) *Journal of Desalination and Water Reuse*, Vol.5, No. 2 (2013 pp 64-74.)
74. "Supply chain design for the global expansion of manufacturing capacity in emerging markets," (with Stefan Weiler, DayÄjn PÄjez, Jung-Hoon Chun, Gisela Lanza), *CIRP Journal of Manufacturing Science and Technology* , Vol. 4, No. 3 (265-280), 2011.
75. "A network flow approach for tactical resource planning in outpatient clinics,"(with Thu Ba T. Nguyen, Appa Iyer Sivakumar), *Health Care Management Science*"(2014): 1-13.
76. "Desalination supply chain decision analysis and optimization," (with Malak T. Al-Nory, Alexander Brodsky, BurÄşin Bozkaya), *Desalination*"Vol. 347 (2014), pp. 144-157.
77. "Making Better Fulfillment Decisions on the Fly in and Online Retail Environment" (with J. Acimovic), *Manufacturing & Service Operations Management*, Winter 2015, Vol. 17, No. 1, pp 34-51.
78. "Setting Optimal Production Lot Sizes and Planned Lead Times in a Job Shop System," (with Rong Yuan), *International Journal of Production Research*, DOI: 10.1080/00207543.2015.1073859.
79. "OM Forum - Practice-Based Research in Operations Management: What It Is, Why Do It, Related Challenges, and How to Overcome Them," (with Jeremie Gallien and Alan Scheller-Wolf) *Manufacturing & Service Operations Management*, Winter 2016, Vol. 18, No. 1, pp 5- 14.,Ä <http://dx.doi.org/10.1287/msom.2015.0566>
80. "Strategic safety stock placement in supply chains with capacity constraints," (with Tor Schoenmeyr) published online in *Manufacturing & Service Operations Management*.
81. "Inventory Management in a Consumer Electronics Closed-Loop Supply Chain," (with Andre Calmon), INSEAD Working Paper No. 2016/39/TOM , June 2016. Available at

SSRN:<https://ssrn.com/abstract=2622405> or <http://dx.doi.org/10.2139/ssrn.2622405>. To appear in *Manufacturing & Service Operations Management*.

82. "Scheduling rules to achieve lead-time targets in outpatient appointment systems," (with Thu Ba T. Nguyen, Appa Iyer Sivakumar), to appear in *Health Care Management Science* (2016), <http://dx.doi.org/10.1007/s10729-016-9374-2>.

83. "No Magic Bullet: A theory-based meta-analysis of Markov transition probabilities in studies of service systems for persons with serious mental illness," (with H. Stephen Leff, Clifton Chow) to appear in *Psychiatric Services* (2016), <http://dx.doi.org/10.1176/appi.ps.201500523>.

84. "Mitigating Spillover in Online Retailing via Replenishment," (with J. Acimovic), April 2014, revised September 2016, 40 pp. Available at SSRN: <https://ssrn.com/abstract=2459097> or <http://dx.doi.org/10.2139/ssrn.2459097>. To appear in *Manufacturing & Service Operations Management*.

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## Proceedings

1. "A Mathematical Programming Procedure for Equipment Selection and System Evaluation in Programmable Assembly," (with D.E. Whitney), *Proceedings of the 18th IEEE Conference on Decision and Control*, Fort Lauderdale, Florida, December 1979 (invited paper, not refereed), 531-536.
2. "Extensions to a Tactical Planning Model for a Job Shop," *Proceedings of the 27th IEEE Conference on Decision and Control*, Austin, Texas, December 1988, pp. 1850-1855. Also Sloan School of Management, M.I.T. Working Paper No. 20-9688.
3. "Using Simulated Annealing to Select Least-Cost Assembly Sequences," (with J. M. Milner and D. E. Whitney), *Proceedings of IEEE Conference on Robotics and Automation*, May 1994.
4. "Spatial Yield Modeling for Semiconductor Wafers," (with A. I. Mirza, G. O' Donoghue, and A. W. Drake), *Proceedings of IEEE/SEMI Advanced Semiconductor Manufacturing Conference*, November 1995.
5. "Strategic Safety Stock Placement in Supply Chains," (with S. Willems) *Proceedings of the 1996 MSOM Conference*, Dartmouth College, Hanover NH, June 1996, pp. 299 - 304.
6. "Optimizing Monsanto's Supply Chain under Uncertain Demand," (with C. Gutierrez, M. Pulwer, H. Sidhu and G. Weihs), *Annual Conference Proceedings - Council of Logistics Management*, Orlando FL, October 1996, pp. 501-516.
7. "Optimizing the Supply-Chain Configuration for New Products," (with S. P. Willems), *Proceedings of the 2000 MSOM Conference*, Ann Arbor, MI, 2000, 8 pp.
8. "Tactical Shipping and Scheduling at Polaroid with Dual Lead-Times," (with Kermit Threatte), *Proceedings of the 2002 SMA Conference*, Singapore, 2002, 8 pp.

9. "A Base Stock Inventory Model for a Remanufacturable Product," *Proceedings of the 2003 SMA Conference*, Singapore, 2003, 7 pp.
10. "Optimizing Safety Stock Placement in General Network Supply Chains," (with K. Lesnaia), *Proceedings of 2004 SMA Conference*, Singapore, 2004, 6 pp.
11. "Traditional Inventory Models in an E-Retailing Setting: A Two-Stage Serial System with Space Constraints," (with R. Allgor and P. Xu), *Proceedings of 2004 SMA Conference*, Singapore, 2004, 6 pp.
12. ""Logistics Network Design with Differentiated Delivery Lead-Time: Benefits and Insights," (with M.L.F. Cheong, and R. Bhatnagar), *Proceedings of 2005 SMA Conference*, Singapore, 20 pp.
13. "An Extension to the Tactical Planning Model for a Job Shop: Continuous-Time Control," (with C. C. Teo, and R. Bhatnagar), *Proceedings of 2005 SMA Conference*, Singapore, 8 pp.
14. "The Complexity of Safety Stock Placement in General-Network Supply Chains," (with K. Lesnaia, and I. Vasilescu ), *Proceedings of the 2005 SMA Conference*, Singapore," 5 pp.
15. "The Benefits of Re-Evaluating Real Time Fulfillment Decisions," (with P. Xu and R. Allgor), *Proceedings of 2005 SMA Conference*, Singapore, 7 pp.
16. "Performance Analysis of Order Fulfillment for Low Demand Items in E-tailing," (with P. Chhaochhria), *Proceedings of 2007 SMA Conference*, Singapore, 5 pp.
17. "Capacity Planning in a General Supply Chain with Multiple Contract Types," (with X. Huang), *Proceedings of 2007 SMA Conference*, Singapore, 6 pp.
18. "Reusing Personal Computer Devices – Good or Bad for the Environment?," (with S. Sahni, A. Boustani and T. Gutowski) IEEE/International Symposium on Sustainable Systems and Technology, Washington D.C, 2010
19. "Appliance Remanufacturing and Life Cycle Energy and Economic Savings,". (with S. Sahni, A. Boustani and T. Gutowski) IEEE/International Symposium on Sustainable Systems and Technology, Washington D.C, 2010.
20. "Water Desalination Supply Chain Modeling and Optimization" (with Malak T. Al-Nory), Data Engineering Workshops (ICDEW), 2013 IEEE 29th International Conference, April 2013

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### **Working Papers and Technical Reports**

- W1. "The Travelling Salesman Problem and Related Problems," (with B. Gavish), Operations Research Center, M.I.T., Working Paper No. 078-78, July 1978, revised and retitled, March 1981.
- W2. "A Research Agenda for Models to Plan and Schedule Manufacturing Systems," (with C. Abraham, B. Dietrich, W. Maxwell, and C. Yano), Sloan School of Management, M.I.T., Working Paper No. 1689-85, revised July 1985.

W3. "Principles on the Benefits of Manufacturing Process Flexibility," (with W. C. Jordan), Sloan School of Management, M.I.T. Working Paper No. 3296-91-MSA, May 1991 (GM Research Laboratories Research Publication GMR-7310).

W4. "An Analytic Approach for Demonstrating the Benefits of Limited Flexibility," (with W. C. Jordan), Sloan School of Management, M.I.T. Working Paper No. 3297-91-MSA, May 1991 (GM Research Laboratories Research Publication GMR-7341).

W5. "Creating an Inventory Hedge for Markov-Modulated Poisson Demand: Application and Model," ( with H. S. Abhyankar) , January 2000, long version. (short version published in M&SOM; see publications).

W6. "Optimizing Strategic Safety Stock Placement in Supply Chains," (with S. Willems), August 1998, long version. (short version published in M&SOM; see publications).

W7. "Strategic Inventory Placement in Supply Chains: Nonstationary Demand," (with S. Willems), August 2002 working paper (substantially revised version published in M&SOM, see publications).

W8. "A Constant-Inventory Tactical Planning Model for a Job Shop," (with J. S. Hollywood)," working paper, January 2001, revised March 2004, January 2006, 36 pp.

W9. "A Dual-Channel Vendor-Buyer System with Minimum Purchase Commitment," with (Y. Wang and R. Bhatnagar), working paper, June 2008, 33 pp.

W10. "Capacity Planning in a General Supply Chain with Multiple Contract Types " Single Period Model," (with Xin Huang), June 2008, revised September 2008, 41 pp

W11. "Velocity-based Storage Assignment in Semi-automated Storage System," (with Rong Yuan and Tolga Cezik). July 2016, 32 pp.

W12. "Performance Evaluation of Material Separation in Material Recovery Facility using a Network Flow Model," (with Karine Ip, Mariapaola testa, Anne Raymond, and Timothy Gutowski), December 2016, 10pp.

### Teaching Cases

1. "Steel Works, Inc, prepared by David Kletter, 1996
2. "Meditech Surgical, prepared by Bryan Gilpin, 1995.
3. "Apollo Paper Company, prepared by Charles DeWitt, 1995.
4. "Use of a Queuing Model to Design a Lean System, prepared by Jamie Flinchbaugh, 2002
5. "The Challenge at Instron, prepared by Dan Wheeler, 2000.
6. "H. C. Starck, Inc., prepared by Thomas J. Carroll, 2000.
7. "Ford Pan-European Durable Containers, prepared by Carmelo Anthony Palumbo, 2002.

8. "Reebok NFL Replica Jerseys: A Case for Postponement, prepared by John C. W. Parsons, 2005.
9. "American Axle and Manufacturing: Determining the Optimal Number of Bar Lengths for Axle Shaft Production, prepared by Heath Holtz, 2005."
10. Production Planning for Chemical Manufacturing, prepared by Shardul Phadnis, 2007.

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### **Invited Presentations (Partial List)**

1. "Improved Scheduling for Automatic Warehousing Systems: Simulation Tests," (with W.H. Hausman and L.B. Schwarz), Joint ORSA/TIMS National Meeting, New York, New York, May 1978.
2. "Logistic Failure vs. Mission Failure in Reliability Specifications," (with J. Keilson), Department of Defense Acquisition Research Symposium, Hershey, Pennsylvania, June 1978.
3. "A Methodology for Studying the Dynamics of Extended Logistics Systems," (with J. Keilson), Conference on Multi-Echelon Inventory Systems, George Washington University, November 1978.
4. "Multistage Lot-Sizing: An Iterative Procedure," Joint ORSA/TIMS Meeting, New Orleans, May 1979 (Also Purdue, April 1979).
5. "The Introduction of Feedback into a Hierarchical Production Planning System," TIMS XXIV International Meeting, Honolulu, June 1979.
6. "Production Scheduling: Theory and Practice," TIMS XXIV International Meeting, Honolulu, June 1979.
7. "System Balance for Extended Logistics Systems," (with J. Keilson), Conference on Multi-Echelon Inventory Systems, Philadelphia, Pennsylvania, November 1979.
8. "Base Stock Systems for Multistage Planning," Conference on Multi-Echelon Inventory Systems, Chapel Hill, North Carolina, June 1980.
9. "Optimization-Based Approaches to Vehicle Routing Problems," (with T.L. Magnanti), Joint ORSA/TIMS National Meeting, Colorado Springs, Colorado, November 1980.
10. "A Mathematical Programming Heuristic for Manufacturing System Design and Evaluation," (with B.W. Lamar) CORS/TIMS/ORSA National Meeting, Toronto, May 1981.
11. "The Dynamics of a Multiechelon Inventory System for a Repairable Item," (with J. Keilson), ORSA/TIMS National Meeting, Houston, October 1981.
12. "A Study of Production Smoothing in a Job Shop," (with A.B. Cruickshanks and R.D. Drescher), TIMS/ORSA National Meeting, Detroit, April 1982.
13. "Scheduling of Re-entrant Flow Shops," (with H.C. Meal, D. Stefek, A.H. Zeghini), TIMS/ORSA National Meeting, Chicago, May 1983.

14. "An LP Planning Model for a Mental Health Community Support System," (with M. Dada and H.S. Leff), ORSA/TIMS National Meeting, Orlando, November 1983.
15. "Operational Analysis of a Job Shop," TIMS/ORSA National Meeting, San Francisco, May 1984.
16. "Two-Stage Production Planning in a Dynamic Environment," (with H.C. Meal), ORSA/TIMS National Meeting, Dallas, November 1984.
17. "Determining the Spares and Staffing Levels for a Repair Depot," TIMS/ORSA National Meeting, Boston, May 1985.
18. "Developing and Use of a Production Flow Plan," ORSA/TIMS National Meeting, Atlanta, November 1985.
19. "Safety Stocks in Manufacturing Systems," ORSA/TIMS National Meeting, Miami, October 1986.
20. "Equipment Selection and Task Assignment for Multiproduct Assembly System Design," (with C.A. Holmes), ORSA/TIMS National Meeting, St. Louis, October 1987.
21. "A Multiechelon Inventory Model for Fixed Reorder Intervals," TIMS/ORSA National Meeting, Washington, DC, April 1988.
22. "Production Planning in a Dynamic Environment," ORSA/TIMS National Meeting, Denver, October 1988. (Also, Yale, November 1988, Carnegie-Mellon, April 1989.)
23. "Cyclic Schedules in Stochastic Environments," CORS/TIMS/ORSA National Meeting, Vancouver, Canada, May 1989.
24. "Production Planning over a Multiplant Operation," ORSA/TIMS National Meeting, Philadelphia, October 1990.
25. "Principles on the Benefits of Manufacturing Flexibility," (with W. C. Jordan), TIMS/ORSA National Meeting, Nashville, May 1991. (Also, University of Minnesota, February 1991, Ohio State, November 1991).
26. "Some Thoughts on Inventory Modeling and Diagnostics," UCLA Conference in Honor of El Buffa, Los Angeles, November 1991.
27. "Reducing Flow Time in Aircraft Manufacturing," (with Jackson Chao), ORSA/TIMS National Meeting, San Francisco, October 1992.

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### **Thesis Supervision (Partial List)**

- R. Blake, "Allocation of Items Under Fixed Capacity," M.S., June 1978 (reader).
- M. Pendrock, "A Hierarchical Approach to Integrated Production and Distribution Planning," M.S. June 1978 (reader).

A. Dutra, "The Impact of Multiple Objectives on Strategic Decision Making: A Case Analysis of the *Sloan Management Review*," M.S., June 1979.

N. Zarin, "A Mathematical Model of the Deinstitutionalization of the Cambridge-Somerville Mental Health Region," M.S., June 1979.

M. Cross, "Business Planning for Small Manufacturing Companies," M.S., June 1980.

B. Lamar, "Optimal Machine Selection and Task Assignment in an Assembly System Design Problem," M.S., September 1980.

M. Ibrahim, "Modeling and Analysis of Automated Manufacturing Systems with Focus on Equivalence and Computational Complexity," M.S., May 1981.

M. Neel, "A Contract Engineering Model, A Work Force Management Tool," M.S., April 1981.

T. Quinlan, "Management Information and Control Systems for Hospital Supplies: A Case Study," M.S., June 1981.

A.B. Cruickshanks and R.D. Drescher, "A Case Study of Production Smoothing in a Job Shop Environment," Joint M.S., February 1982.

D. Stefek, "A Periodic Production Scheduling Problem," M.S., June 1982.

C. Olson, "A Prototype System for Hierarchical Production Planning," M.S., June 1983.

D. Choing, "The Role of Buffer Stocks in a Re-Entrant Flow Shop," M.S., June 1983.

R. Gould, "Quantitative Tools for the Optimization of Selling Efforts in Metropolitan Cable Television Systems," M.S., February 1984.

P.C. Santos, "An Optimization Model for the Configuration of Incoming WATS Lines," M.S., June 1984.

A.H. Zeghmi, "Inventory Buffers for a Production Line with Controllable Production Rates," Ph.D., September 1985.

C.A. Holmes, "Equipment Selection and Task Assignment for Multiproduct Assembly System Design," M.S., January 1987.

S.H. Parrish, "Extensions to a Model for Tactical Planning in a Job Shop Environment," M.S., June 1987.

S. Mihara, "A Tactical Planning Model for a Job Shop with Unreliable Work Stations and Capacity Constraints," M.S., January 1988.

J. Wagner, "Stochastic Programming with Recourse Applied to Groundwater Quality Management," Ph.D., June 1988.

G. Sy-Quia, "A Study of Production Loading in a Job Shop," M.S., June 1988.

- L. Dickey, "Where Should Safety Stock be Held to Minimize Costs and Maximize Flexibility?" M.S., May 1989.
- G. Amblard, "Rationale for the Use of Subassemblies in Production Systems: A Comparative Look at Sequential and Arborescent Systems," M.S., May 1989.
- C. Coopridge, "Equipment Selection and Assembly System Design Under Multiple Cost Scenarios," M. S., June 1989.
- E. Reifschneider, "Scheduling Jobs in a Multi-Station Plant," B.S., June 1989.
- S. Pappu, "A Dual-Ascent Algorithm for Finding the Optimal Testing Strategy," M.S., June 1989.
- H. Zhang, "Cyclic Scheduling in a Stochastic Environment," Ph. D., May 1990.
- C. Fu, "An Investigation of the Development of Product Design Specifications: A Conceptual Development and a Case Study," M.S., June 1990.
- R. Munroe, "A Framework for Product Development Based on Quality Function Deployment, Traditional Decision-Making Theory, and Design Practice," M.S., June 1990.
- R. M. Coleman, "The Effects of Design, Manufacturing Processes, and Operations Management on the Assembly of Aircraft Composite Structure," M.S., June 1991.
- C. Papouras, "Lead Time and Inventory Reduction in Batch Chemical Manufacturing," M.S., June 1991.
- T. Taylor, "Evaluating and Selecting Manufacturing Flexibility," M.S., June 1991.
- K. Elsesser, "The Validation of a Simulation Model for the Allocation of Mental Health Services," M.S., June 1991.
- J. Chao, "Analysis of Variance Impact on Manufacturing Flow Time," M.S., June 1991.
- B. Koetje, "Improving Cycle Times in Batch Chemical Operations," M.S., June 1991.
- C. Athaide, "Capacity Allocation and Safety Stocks in Manufacturing Systems," Ph. D., June 1992.
- M. Burke, "Optimizing Product Life Cycles in the U. S. Auto Industry," M.S., June 1992.
- C. Dennison, "Electric Shock Risks in an Electric Vehicle," M.S., June 1992.
- D. Hager, "Applying Continuous-Flow Manufacturing Principles to a Low-Volume Electronics Manufacturer," M.S., June 1992.
- L. Hsu, "The Design of an Assembly Line with Stochastic Task Times," M.S., June 1992.
- C. Jutte, "Lead Time Reduction for Multiple Step Batch Chemical Processes," M.S., June 1992.
- T. Mock, "Reducing Process Variability in Chemical Batch Manufacturing," M.S., June 1992.
- S. Pappu, "Production Planning with Due-Date Constraints," Ph. D., June 1992.

- L. Spiridigliozzi, "Precision Laser Micromachining of Ceramics, " M.S., June 1992.
- K. D. Bartelson, "Analysis and Redesign of the Production System Structure for 757 and 737 Aircraft Doors," M.S., June 1993.
- M. J. Blatz, "Designing Measurement Systems in a Manufacturing Environment, " M.S., June 1993.
- M. Chrzanowski, "Development of a Manufacturing & Business Planning Tool to Aid in Forward Planning, " M.S., June 1993.
- W. B. Hetzel, "Cycle Time Reduction and Strategic Inventory Placement Across a Multistage Process," M.S., June 1993.
- J. A. Rennert, "Measuring Customer-Driven Manufacturing Process Improvement in a Multidivisional Corporation, " M.S., June 1993.
- D. J. Seitelman, "Scheduling Employees of a Manufacturing Facility, " M.S., June 1993.
- S. K. Jacobsmeyer, " Implementing Flow Time Reduction Using Process Mapping and Innovation," M.S., June 1994.
- D. B. Kletter, "Determining Production Lot Sizes and Safety Stocks for an Automobile Stamping Plant," M.S., June 1994.
- J. Ku, "Microprocessor Manufacturing Throughput Time Variability," M.S., June 1994.
- L. R. Oliver, "Process and Productivity Improvements through Bottleneck Reduction and Design of Experiments," M.S., June 1994.
- B. K. Parks, "Cost and Lead Time Reduction in the Manufacture of Injection Molding Tools," M.S., June 1994.
- M. A. Raftery, "Using the Seven-Step Method to Reduce Defects in a Polymer Sheet Making Process," M.S., June 1994.
- K. Y. Tan, "Minimizing the Impact of Model Changeover at a Medium-Mix High-Volume Cellular-Telephone Production Line," M.S., June 1994.
- C. M. Dewitt; "A Holistic Approach to Automotive Powder Coating," M.S., June 1995.
- K. L. Homsí, "Information Flow and Demand Forecasting Issues in A Complex Supply Chain," M.S., June 1995.
- P. Gallagher, "Molding Process Development for Fuel Cell Components," M.S., May 1995.
- A. E. Koszarek, "Module Based Configuration Definition to Enable Design Re-Use and Manufacturing System Simplification in the Commercial Aircraft Industry," M. S., June 1995.
- A. I. Mirza, "Spatial Yield Modeling for Semiconductor Wafers," M.S., May, 1995.
- T. R. Wadewitz, "Analysis of Investments in Process Control Tools: Laser Scanners Used For On-Line Inspection in a Polyester Sheet Production Process," M.S., June, 1995.

- M. I. Zeni, "Five Axis Machining of Stamping Dies," M.S., May 1995.
- Roberta Bailey, "A Data-Driven Approach to Improving Capacity Utilization of Semiconductor Test Equipment," M.S., June 1996.
- James Beuerle, "A Study of Electrostatically Applied Powder Paint in the Automotive Industry," M.S., June 1996.
- Michael Carnette, "Implementing Internal Supply Chain Improvements", M.S., June 1996.
- Barrett Crane, "Cycle Time and Cost Reduction in a Low Volume Manufacturing Environment," M.S., May 1996
- Audrey Dima, "Improving the Recovery Process of Circuit Boards in a One-Time-Use Camera," M.S., June 1996
- Mark MacLean, "Implementing Lean Manufacturing in an Automobile Plant Pilot Project," M.S., June 1996
- Cristian Gutierrez, "Development and Application of a Linear Programming Model to Optimize Production and Distribution of a Manufacturing Company," M.S., February 1996
- Sumer Johal, "A Simulation-Based Study of the Cost and Performance Trade-Offs in a Semiconductor IC Manufacturing Facility," M.S., May 1996
- Sean Willems, "Strategic Safety Stock Placement in Integrated Production/Distribution Systems," M.S., May 1996
- Rebecca D'Amato, "Allocating Housing Resources for a Psychiatric Program," M.S., June 1996
- David B. Kletter, "Planning and Control of an Unreliable Machine in a Multi-Item Production-Inventory System," Ph. D., June 1996
- Jeffrey Alcalde, "The Design and Implementation of a Synchronous Manufacturing System In a Job-Shop Environment," M.S., June 1997.
- Liana Alvarez, "Design and Implementation of Cellular Manufacturing in a Job Shop Environment," M.S., June 1997.
- Daniel Crocker, "Analysis of Global Manufacturing Strategies For High Volume High Technology Products," M.S., June 1997.
- Jennifer Felch, "Supply Chain Modeling For Inventory Analysis," M.S., June 1997.
- Joetta L. George, "Applying the Theory of Constraints in a High Volume Manufacturing System to Increase Throughput and Performance," M.S., June 1997.
- Steven Harman, "Implementation of Lean Manufacturing and One-Piece Flow at Allied Signal Aerospace," M.S., June 1997.

Thomas Jacob, "Root Cause Analysis of Low On-Time Delivery Performance at a Computer Manufacturing Plant," M.S., June 1997.

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R. Lawrence Coughlin, III, "Optimization and Measurement of a World-Wide Supply Chain," M.S., June 1998.

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David Medrow, "Cost Modeling of a Manufacturing Process," M.S., June 1998.

Nicholas Purzer, "Managing the Supply, Release, and Machining of Material Within an Aerospace Component Shop," M.S., June 1998.

John D. Ruark, "Implementing Reusable Solvers: An Object-Oriented Framework for Operations Research Algorithms," Ph.D., June 1998.

Sean P. Willems, "Two Papers in Supply Chain Design: Supply Chain Configuration and Part Selection in Multigeneration Products," Ph.D., February 1999.

Michael Dickinson, "Technology Portfolio Management: Optimizing Interdependent Projects Over Multiple Time Periods," M.S., June 1999.

Thomas Furey, "Decision Elements in the Design of a Consumer Electronics Assembly Plant," M.S., June 1999.

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John Kang, "Applying Six Sigma to Tenneco Automotive Manufacturing," M.S., June 1999.

Michael Kimber, "Definition and Implementation of a Visual Inventory Management System," M.S., June 1999.

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Thor Sewell, "Understanding and Controlling Risk in Product Development, Specifically in New Technology Procurement, at an Automatic Test Equipment Manufacturer," M.S., June 1999.

Hari S. Abhyankar, "Inventory Control for High Technology Capital Equipment Firms," Ph.D. February 2000.

Matthew F. Bromberg, "Modeling Design Rework in a Product Development Process," M.S., June 2000.

Thomas J. Carroll, "Using Postponement to Move from Job-Shop to a Mixed MRP/Job Shop Environment," M.S., June 2000.

John S. Hollywood, "Performance Evaluation and Optimization Models for Processing Networks with Queue-Dependent Production Quantities," Ph. D., June 2000.

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Brian A. Urkiel, "The Analysis and Optimization of the Alcoa Mill Products Supply Chain for European Customers," M.S., June 2000. "\*\*\*\*\*"

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"Jonathan E. Howe, "Minimizing the Risk Qualification Test Wafers Have On The Manufacturing Readiness of a New Microprocessor Fabrication Site Through Data Driven Processes," M.S., June 2001.

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Matthew W. Street, "Quick Response Inventory Replenishment for a Photographic Material Supplier," M.S., June 2001.

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Andrea L. Vlasak, "Integration of Third Party Logistics Providers Within the Distribution Network," M.S., June 2001.

Julie L. Wilhelmi "Analyzing the Boeing 777 Link the Flow Process for Value Stream Flow Reduction Against the Lean Aerospace Initiative's Enterprise Level Roadmap," M.S., June 2001.

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Qian Wu "A Supply Chain Strategy for Digital Camera Products," M.S., June 2001.

Gregory S. Chalker, "The Use of Modeling and Critical Operations Data To Optimize Plant Performance," S.M., May 2002.

Dan Grotzky, "A New Framework for Making Sourcing Decisions Regarding Low-Volume, High-Complexity Products," S.M., June 2002.

Emanuele F. Gillio, "Lean Principles Applied to a Supply Chain with Demand Uncertainty," S.M., June 2002.

Eric W. Partlan, "An Alternative Method of Long Lead-Time Tool Purchases," S.M., June 2002.

Clinton J. Rockwell, "A Framework for Optimizing the Supply Chain:" A Case Study as Kodak," S.M., June 2002.

Robert L. Scholtz III, "Strategies for Manufacturing Low Volume Semiconductor Products in a High Volume Manufacturing Environment," S.M., June 2002.

Eric Jan, "Supply Chain Performance Improvement Through Forecasting," S.M., June 2002.

Sheila J. Bragg, "Analysis of Sorting Techniques in Customer Fulfillment Centers," S.M., June 2003.

M. Carla Eustache, "Integrating Cost Consciousness into a High Quality Manufacturing Environment," S.M., June 2003.

Eric D. Green, "Optimization of Photochemical Production Using Lean Manufacturing Philosophies," S.M., June 2003.

Mark Kamal, "Management of Regional Local Content Regulations at Dell Computer Corporation," S.M., June 2003.

Don J. Lee, "End-of-Life Supply Chain Strategy for High-Performance Servers," S.M., June 2003.

Scott A. Rosenberg, "Managing a Data Analysis Production Line:" An Example from the Whitehead/MIT Center for Genomic Research," S.M., June 2003.

Eric A. White, "Lean Enterprise Distribution Tactics with Customer Supply Chain Integration," S.M., June 2003.

Mark Hagan, "Process for Evaluating Options for Materials Management Outsourcing," S.M., June 2004.

Stephen G. King, "Using Value Stream Mapping to Improve Forging Processes," S.M., June 2004.

Michael A. Zeppieri, "Predictive Capacity Planning Modeling with Tactical and Strategic Application," S.M., June 2004.

Haitao Liu, "The Development and Implementation of a Production Information Collection and Reporting System," S.M., June 2004.

William Kwong, "Reducing Variability in Equipment Availability at Intel using Systems Optimization," S.M., June 2004.

Padmaja S. Vanka, "Line Coordination in a Rapid Change, High Volume Environment," S.M., June 2004.

Ekaterina Lesnaia, "Optimizing Safety Stock Placement in General Network Supply Chains," Ph.D., September 2004.

John C.W. Parsons, "Using A Newsvendor Model for Demand Planning of NFL Replica Jerseys," M. Eng., June 2004.

Jeffrey D. Johnson, "Managing Variability in the Semiconductor Supply Chain," S.M., February 2005

Jason Walker Connally, "Introducing Pull Methodologies in a Semiconductor Fab," S.M., June 2005.

G. Thomas Heaps-Nelson, "Analyzing and Improving Throughput of Automated Storage and Retrieval Systems in Personal Computer Manufacturing," S.M., June 2005.

Heath M. Holtz, "Re-sourcing Manufacturing Processes in Metal Forming Operations," S.M., June 2005.

Carlos Mazariegos, "Bath Sizing Strategy and Production Load Leveling in a Multi-Step Chemical Manufacturing Process," S.M., June 2005.

Kevin McKenney, "Development and Application of Management Tools within a High-Mix, Low-Volume Lean Aerospace Manufacturing Environment," S.M., June 2005.

John M. Palmer, "Level Loading and Cross Docking in a Global Logistics Network," S.M., June 2005.

Mira K. Sahney, "Building Operational Excellence in a Multi-Node Supply Chain," S.M., June 2005.

Ronak R. Shah, "A Systems Approach to the Evaluation of Radio Frequency Identification (RFID) in the Defense Industry," S.M., June 2005.

Roy C. Wildeman, Jr., "An Application of Lean Principles within a Semiconductor Manufacturing Environment," S.M., June 2005.

Claudia Wu, "Total Supply Chain Cost Model," S.M., June 2005.

Ping Josephine Xu, "Order Fulfillment in Online Retailing: What Goes Where," Ph.D., September 2005.

Cheong Lee Fong, Michelle, "New Models in Logistics Network Design and Implications for 3PL Companies," Ph.D., NTU, August 2005.

Teo Chee Chong, "A Tactical Planning Model for Make-To-Order Environment under Demand Uncertainty," Ph.D., NTU, May 2006.

Craig B. Abler, "Material Evaluation and Selection Processes to Enable Design for Manufacture," S.M., May 2006.

Yue (Cathy) Chang, "Getting Ahead in Sourcing Through Benchmarking and System Dynamics Analysis:" An Aerospace Industry Perspective," S.M., June 2006.

Rebecca Cassler Fearing, "Managing Preventative Maintenance Activities at Intel Corporation," S.M., June 2006.

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